



Contents lists available at ScienceDirect

Journal of Nuclear Materials

journal homepage: www.elsevier.com/locate/jnucmat



Thermo-mechanical analysis of LWR SiC/SiC composite cladding

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A B S T R A C T

A dedicated framework for thermo-mechanical analysis of the in-pile performance of SiC/SiC composite fuel cladding concepts in LWRs has been developed. This analysis framework focuses on cladding and omits any fuel-cladding interaction and fuel behavior. Since radial expansion of the cladding occurs early in life for these ceramic structures, fuel-cladding contact is expected to be delayed or eliminated and therefore it is not considered in this analysis. The analysis inputs recent out-of-pile and in-pile materials property data and phenomenological understanding of material evolution under neutron irradiation for nuclear-grade SiC/SiC composites to provide a best-estimate analysis. The analysis provides insight into the concept design and feasibility of SiC/SiC composite cladding concepts that exhibit significantly different behavior than metallic cladding structures. In particular, absence of any tangible creep (thermal or irradiation) coupled with a large and temperature-gradient-driven irradiation swelling strain gradient across the cladding, drive development of large stresses across the cladding thickness. The resulting analysis indicates that significant stresses develop after a modest neutron dose (~ 1 dpa) and a pronounced variation across the cladding thickness exists and is opposite to that observed for metallic cladding structures where swelling or growth strains are either negligible (with small temperature dependence) or absent. Following this thermo-mechanical analysis, a best-estimate and parametric examination of SiC/SiC fuel rod cladding structures has been performed using appropriate Weibull statistics to prescribe basic design guidelines and to begin to define a probable design space.

The above paper on accident tolerant fuel cladding was published in a previous issue of the Journal of Nuclear Materials 447 (2014) 125–142.